Mars Global Surveyor Orbit Determination Uncertainties Using High Resolution Mars Gravity Models

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Orbit determination of the Mars Global Surveyor performed at the Jet Propulsion Laboratory was conducted for the purpose of refining the Mars gravity field, as part of the radio science investigation. The orbit determination was performed using X-band one-way, two-way, three-way Doppler data, collected primarily from the DSN 34m HEF tracking stations. A description of the mission and its trajectory will be provided, followed by a discussion of the orbit determination estimation procedure and models. Accuracies will be examined in terms of orbit-to-orbit solution differences, and are determined for the latest 75th degree gravity model for the nominal mission.

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ABSTRACT

The Mars Global Surveyor (MGS) mission began on November 7, 1996, when the MGS spacecraft was launched from Cape Canaveral, Florida. The science objectives for this mission were to study the Mars atmosphere, geology, surface-atmosphere interaction, determine a global composition map and a topographic map of the surface, and improve knowledge of the magnetic and gravity fields for one Martian year. Orbit determination of MGS performed at the Jet Propulsion Laboratory (JPL) is conducted as part of the radio science investigation of the Mars gravity field. This paper will describe the JPL effort in support of this investigation. This support includes high precision orbit determination, gravity model validation, and data editing. A description of the mission and its trajectory will be provided first, followed by a discussion of the orbit determination estimation procedure and models. Accuracies will be examined in terms of orbit-to-orbit solution differences.

The Mars Global Surveyor spacecraft was launched on November 7, 1996 aboard a Delta II vehicle. MGS arrived at Mars on September 11, 1997 and was placed into a highly elliptical near polar orbit with a periapsis altitude of 260 km, an apoapsis altitude of 54,000 km, and an orbit period of 45 hours. On September 17, 1997, aerobraking was implemented on MGS in which the spacecraft was repeatedly passed through the upper atmosphere of Mars to slow itself down by means of air resistance, resulting in a lower apoapsis. The original mission plan was to use this aerobraking scheme to lower the apoapsis altitude from 54,000 km to 450 km over a four month period. However, on October 11, 1997 the scheme was suspended after one of the two solar panels on the spacecraft was bent backward because the air pressure on MGS was too high. Aerobraking resumed on November 7, 1997, after flight team members determined that aerobraking could be safely performed on MGS at a more gentle pace than originally planned. The new plan involved two gentle aerobraking phases (the first from early Nov '97 to the end of Mar '98 and the second from the end of Sep '98 to the early part of Feb

'99), two science phases (the first from late Mar '98 to the end of Apr '98 and the second from early Jun '98 to the end of Sep '98), and a quite period (from the end of Apr '98 to the beginning of Jun '98) during the solar conjunction period. The suspension of the aerobraking was necessary for two reasons: the first was to avoid aerobraking operations with degraded tracking data due to solar conjunction; the second was to allow the orbit of MGS to drift into the desired sun-synchronous orientation. To maximize the efficiency of the mission, MGS collected as much science data as possible during this period of suspension. On March 29, 1999, MGS officially began its mapping phase of the mission from a near polar circular orbit with an orbit period of about 2 hours and a periapsis altitude of 380 km. The nominal mission ended on January 31, 2001.

The orbit determination of MGS is performed by using X-band one-way, two-way, three-way Doppler and range data collected primarily from the Deep Space Network 34m diameter HEF tracking stations. The near continuous Doppler data is compressed and used in the orbit determination process as 10 second sample rate data, with outages occurring as long as 42 minutes due to occultation by Mars. Range data was compressed to 2 minute sample rate data. Invalid data are removed to reduce processing time and corrections to the data include biases, per track station range calibration errors, and station dependent processing errors. High fidelity troposphere and ionosphere calibrations are utilized. Among other things, the spacecraft attitude, high-gain antenna orientation, and Angular Momentum Dump (AMD) information are also used in the orbit determination process.

The orbit determination process solves the following set of estimated parameters: spacecraft state, solar radiation pressure coefficients, drag coefficients, small forces at AMD events, Doppler biases, and range biases. Each set of solutions is usually determined by processing a two-day data arc; sparse radiometric data due to solar conjunction or other reasons cause some data arcs to be longer than two days. The spacecraft is being modeled as a bus with two plates. The dynamic models used in determining the orbit of MGS are the Newtonian point-mass model, the relativity model, the oblateness and solid tide models, the small forces model, the atmospheric drag model, and the solar and Mars radiation pressure models. One-way Doppler data is weighted at 1mm/sec, two- and three-way Doppler data are weighted at 0.1 mm/, and range data is weighted at 2 meters.

A 75th degree and order gravity model, MGS75D, is used to determine the MGS orbit for the nominal mapping mission. Accuracies are determined by comparing one orbit overlap between adjacent solutions. For the nominal mission, results indicate a typical radial, cross-track (out-of-orbit plane), and along-track orbit errors of 0.15, 4, and 10 meters, respectively.

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